AD-A136 264 ENGINE-TRANSMISSION ANGULAR-CONTACT BALL THRUST BEARING 1/1
ENDURANCE TESTS(U) SOUTHWEST RESEARCH INST SAN ANTONIO
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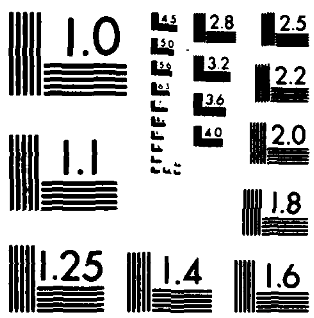

MICROCOPY RESOLUTION TEST CHART
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Six bearings were endurance tested in pairs in a machine utilizing back-to-back loading of the bearing pairs. Each pair of bearings were run using a predetermined speed and load test schedule for 1,000 hours or failure, whichever occurred first. A description of the test program and the results obtained are described.

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November 23, 1983
File: 15-5607-814

Mr. Martin W. Joseph
DRSPS-Q
TSARCOM
4300 Goodfellow Boulevard
St. Louis, MO 63120

Subject: Letter Report of the Engine-Transmission Angular-Contact Ball Thrust Bearing Endurance Tests Conducted Under Contract DLA900-79-C-1266, P00019

Dear Mr. Joseph:

Six (6) bearings, P/N 114DS-668-3, were to be endurance tested in pairs in a machine utilizing back-to-back loading of the bearing pairs under the subject contract. Each pair of bearings were run using a predetermined speed and load test schedule for 1,000 hours or failure, whichever occurred first. A description of the test program and the results obtained are included in the following paragraphs.

Test Bearings. A total of ten (10), 70-mm bore, angular-contact ball bearings, P/N 114DS-668-3, were received from Corpus Christi Army Depot (CCAD), DRSTS-MR, for use on the subject program. The bearings were identified by serial number, as follows:

S/N
69
85
180
203
590
660
810
1637
1957
1991

It is understood that these bearings had been fitted with a new design ball retainer (cage). All the bearings, including the used bearings from this test program, will be returned to CCAD upon completion of the endurance test program.

Lubricant. The lubricant used for all of the endurance tests included in the program was a MIL-L-7808H oil supplied by CCAD.

Test Procedure. The tests were conducted using a thrust bearing machine, shown in Figure 1 attached, especially modified to accept two of the special test bearings supplied. As shown in Figure 1, the two angular contact, ball test bearings (23) are loaded one against the other by means of a pneumatic pressure applied to the diaphram (14) which is transmitted to the load plate (10). The load plate loads the outer race of the front bearing, through the balls of the front bearing to the rear inner race of the front bearing, through the spacer (17) to the front inner race of the rear bearing, through the balls of the rear bearing to the outer race of the rear bearing. The two retainers (11) are used only for retaining the test bearings to the shaft adapter (16) and are not load bearing members. The thrust load, applied as mentioned above, is taken by the support (6), through the studs (9) back to the cover (13). A small cylindrical roller bearing (27) supports the splined end of the machine shaft (2). Three adjusting screws (33), with locknuts (32), equally spaced around the shaft, are used to support the shaft when the test bearings are removed. A magnetic sensor (25), triggered by slots in the machine shaft, is used to determine machine speed during test.

The drive stand used with the thrust bearing machine is powered by a 50-hp electric motor, through a variable speed Dynamatic coupling to the input shaft of a gearbox having a speed capability in excess of 16,000 rpm. Coupling of the thrust bearing machine to the drive stand is effected by an adapter block and splined coupling.

Lubricant was supplied to the two test bearings at 45 ± 5 psig by eight test-oil jets (8) installed between the two test bearings (4 jets, installed 90° from each other, and directed towards each of the two bearings). All the oil supplied by the eight jets (approximately 4800 ml/min) passes through the test bearings. The test oil exits the machine through two scavenge ports, one located in front of the test bearings and the other located behind the test bearings. The test-oil sump temperature was controlled at 200 ± 10°F. No provisions were made to control the test bearing temperatures; however, two thermocouples on each of the test bearing outer races provided a means of recording the operating temperature of each of the test bearings as well as providing an input to preset high-temperature safety controllers which shut the machine down in the event of a test bearing temperature excursion above a preset value. Machine speed was monitored by an rpm indicator which also includes over-and-under speed safety controls which shut the machine down in the event of an over-or-under preset speed indication. A vibration pickup and associated instrumentation, which processes the pickup signal, automatically shut the machine down in the event a pit or spall occurring on either of the test bearings causing the noise level, or vibration level, to increase above a preset background level. A temperature recorder was used to monitor the temperatures of the test-oil sump, test-oil in (to the thrust bearing machine), test-oil out (both front and rear scavenge lines), front test bearing outer race, and the rear test bearing outer race during test.

Prior to starting a bearing endurance test, the oil-wetted surfaces of the thrust bearing machine are thoroughly cleaned and air dried. The test-oil pumps, lines, filters, cooler, and sump were also cleaned and air dried. Two test bearings were installed in the thrust bearing machine, the test oil system assembled, and the sump charged with 2 gallons of new test oil.

To initiate a test, the test-oil sump heaters were turned on and the test oil circulated through the thrust bearing machine until the test-oil temperature reached 200°F. A minimum thrust load of approximately 100 lb was applied to the test bearings. The thrust bearing machine was then started and the shaft speed increased to 13,000 rpm for 0.1 hr (Test Condition 1). The thrust load was then increased to 3500 lb with the shaft speed maintained at 13,000 rpm for 0.1 hr (Test Condition 2). The thrust load and shaft speed were then increased to 6300 lb and 16,000 rpm, respectively (Test Condition 3), for 0.1 hr. The test was continued, cycling between Test Condition 2 and Test Condition 3, each 0.1 hr for eight additional cycles, at which time the rpm was continued at 16,000 rpm and the thrust load reduced to 500 lb (Test Condition 4) for 0.1 hr, thereby completing a 2-hr test sequence. The 2-hr test sequence was repeated 4 times during one 8-hr shift per day. The remaining 16 hr each day was run at a constant thrust load of 6300 lb and a shaft speed of 16,000 rpm (Test Condition 3). A summary of the different test conditions are as follows:

Test Condition	Speed, rpm	Thrust Load, lb	Max. Hertz Stress, psi	Approx. Test Hours per day
1	13,000	100	72,200	0.4
2	13,000	3,500	236,200	3.6
3	16,000	6,300	287,300	19.6
4	16,000	500	123,500	0.4
				24.0

During the test, the test-oil sump temperature, the test-oil in temperature, the test-oil out temperature, and the test bearing outer race temperatures were automatically recorded. Safety limit switches were activated on the test-oil temperature, test-oil pressure, machine shaft speed, and the bearing outer race temperature, systems which shut the machine down in the event of an excursion above or below their preset limits. In addition, an accelerometer was used as a vibration pickup, and a monitor circuit with an adjustable threshold level was provided to detect the occurrence of a spall on the test bearings and automatically shut the machine down.

During all endurance runs, 40-ml samples of the test oil were taken after each 100-hr operating period and the 104°F viscosity, and neutralization number, and iron content determined.

Test Results. Four tests have been completed to date.

Test No. 1. Test bearings S/N 660 and 1991 were evaluated in the first test. These two bearings completed 1,002.5 hr of operation with no significant problems attributable to the test bearings. Upon visual inspection of the two bearings at the end of 1,002.5 hr operation, no indication of spalling was evident in either bearing. Only a very slight amount of wear was evident on the cage of each of the two bearings. This wear occurred between the bearing cage and the inner race of both test bearings. By all indications, both of the test bearings could have continued operation with no problems.

The viscosity of the lubricant at the start of test was 13.16 cs at 104°F and 13.65 cs at 104°F at the end of test. The iron content of the lubricant after 110 hr of operation was 23 ppm. At the end of test, the iron content had increased to only 30 ppm.

Test No. 2. Test bearings S/N 69 and 810 were evaluated in the second test performed. After 330 hr of operation the test rig shut down automatically during overnight operation under Test Condition 3. Approximately 148 hrs operation, or 44.5 percent of the operating time, was accumulated using the Test Condition 1, 2, 3 cycling test procedure. The remaining 182 hrs were accumulated at the constant Test Condition 3. Upon inspection of the test bearings it was determined that S/N 810 bearing had one ball with approximately 15 to 20 percent of its surface area spalled. In addition, two additional balls in the same bearing had spalled areas. One ball had one small spall approximately 1/16-in. diameter and the other ball had four extremely small spalls, all approximately 1/64-in. diameter. Bearing S/N 69 was inspected and no indication of failure was found on the bearing.

The viscosity of the lubricant had increased from 13.20 cs at 104°F to 13.49 cs after 330 hr of operation. The iron content of the lubricant after 310 hr operation was only 12 ppm. However, the sample taken at the end of 330 hours operation included metal particles too large for the AA spectrophotometer to aspirate into the flame and a subsequent X-ray analysis shows greater than 2000 ppm iron.

Test No. 3. Test bearings S/N 85 and 180 were evaluated in the third test performed. After 343.9 hr of operation the test rig shut down automatically during overnight operation under Test Condition 3. Approximately 129.5 hrs operation, or 37.6 percent of the operating time, was accumulated using the Test Condition 1,2,3 cycling test procedure. The remaining 214.4 hrs were accumulated at the constant Test Condition 3. Upon inspection of the test bearings it was determined that S/N 85 bearing had one ball with approximately 5 percent of its surface area spalled. In addition, one spall approximately 3/8-in. diameter was on the inner race of the bearing. Bearing S/N 180 was inspected and no indication of failure was found on the bearing.

The viscosity of the lubricant increased from 13.20 cs at 104°F to 13.62 cs after 343.9 hr of operation. The iron content of the lubricant was determined to be essentially the same as that determined for Test No. 2; namely, a very low iron content noted after 300 hr using the AA spectrophotometer, and at the end of test X-ray analysis showed iron content to be greater than 2000 ppm.

Test No. 4. Due to the fact that two tests were terminated prior to 1000 hr operation, a fourth test was included at no additional cost. Test bearings S/N 590 and 1637 were evaluated in the fourth test performed. After 35.3 hr of operation the test rig shut down automatically during overnight operation under Test Condition 3. Approximately 19.3 hrs operation, or 54.6 percent of the operating time, was accumulated using the Test Condition 1, 2, 3 cycling test procedure. The remaining 16 hrs were accumulated at the constant Test Condition 3. Upon inspection of the test bearings it was determined that S/N 590 bearing had a large spall, approximately 1/4-in. wide by 2-in. long in the outer race of the bearing. No other indication of failure was evident with bearing S/N 590. Two small spalls, one 1/16 in. by 3/16 in. and the other 3/16 in. by 1/4 in., were found on one of the balls in bearing S/N 1637. The two spalled areas on the ball were connected by a crack, approximately 11/64-in. long, visible to the naked eye. No other indications of failure were evident with bearing S/N 1637.

The viscosity of the lubricant increased from 13.20 cs at 104°F to 13.48 cs after 35.3 hr of operation. No data were obtained on the iron content of the lubricant following this short duration test since no earlier base samples were taken.

Discussion of Test Results. A summary of the results from the four tests conducted is presented in the following tabulation:

Test No.	Bearing Serial No.	Time to Failure, hr
1	660	1002.5+
	1991	1002.5+
2	69	330+
	810	330
3	85	343.9
	180	343.9+
4	590	35.3
	1637	35.3

During the visual inspection of the test bearings after test, it was noted that there were several small silver colored spots approximately 1/16-in. to 1/8-in. in diameter on some of the balls and races of the test bearings, as shown in Figure 2. These spots which appeared on the balls and/or loaded portions of the races were readily discernible since they were not as discolored as other portions of the same balls and races. Inspection of typical bright spots and areas outside the bright spots on a selected ball using an Energy Dispersive X-Ray Analyzer (EDAX) gave the charts shown in Figure 3. Figure 3a represents a charting of the elements in an area outside of a bright spot. Figure 3b represents an area on a bright spot. Figures 3c and 3d are expanded scale representations of Figures 3a and 3b, respectively. It will be noted in Figure 3d that the

two peaks identified as Rhodium and Silver do not appear in Figure 3c. The only Silver known to be in the test system is in the plating on the cage of the test bearings. The Rhodium is believed to be perhaps a "flash plate" used prior to the silver plate. It appears that some of the silver plating material is removed from the cage by a wear process in the cage pockets. These silver wear particles or flakes get caught in a loaded zone between a ball and the race/or races of the bearing and are effectively randomly "pressure plated" on to either a ball or a race of the bearing. The silver particles or flakes then become a part of the mating surfaces in the loaded areas of the bearing. This additional material in the loaded areas increases the stress level in the area of the silver spots. The increased stress level in these silver spot areas will have a tendency to increase the chances of a spalling failure occurring in these areas as opposed to the areas of the bearings which do not have "foreign metals" in the loaded areas of the balls and races. The silver spots do not always induce spalls as evident from Figure 2. However, Figure 4 indicates a spall believed to be initiated by the presence of the silver spot. Figure 5 indicates two areas of incipient spallings, both occurring within a silver spot area.

Not all of the spalls noted in these tests can be attributed to the effect of the silver spots in the loaded areas of the bearings. However, the fact that more than one spall occurred in silver spot areas indicates that it is more than a random occurrence and that the silver spots do increase the possibility of spalls in the loaded areas of the bearings.

Silver plating has been used successfully on bearing cages for years, but in many cases the base cage material is a type of bronze, rather than steel. It is suspected that the silver plating used on the current test bearings is either lacking in its adherence to the base metal and/or the silver plating may be of excessive thickness from that used on other bearing cages. No information relative to the preparation of the cage for plating, the plating procedures, or thickness of the silver plate was submitted with the test bearings; and, analyses beyond the inspections presented here are outside the scope of the current contract.

It should be mentioned that there was one known difference in the test conditions relative to Test No. 1 from those used for all three subsequent tests. It was originally reported that the bearings in field service were lubricated by one (1) 0.040-in. oil jet. Therefore, the first preliminary runs on the bearing rig were initiated using 45 psig oil pressure and one 0.040-in. oil jet on each of the two test bearings (S/N 660 and S/N 1991). The most severe speed and load conditions used during the preliminary runs were those identified earlier as Test Condition 3 (16,000 rpm and 6,300 lb thrust load). The bearings were operated at Test Condition 3 using one oil jet on each of the bearings. After approximately 20 minutes of operation, the bearing outer race temperature appeared to stabilize at 425°F, which is considerably above the temperature level anticipated. The rig was stopped and the preliminary runs terminated while additional information on the oil flow to the bearings, which was suspected of being low, was obtained. After numerous phone calls to CCAD, TSARCOM, and Boeing Vertol, it was determined that four (4) 0.032-in. jets were normally used on each bearing with an oil

pressure of 40 to 55 psig. At about that same time, it was understood that the 0.032-in. diameter jets were to be increased in future hardware to 0.040 in. Therefore, the number of jets used with the test bearings was increased to four for each bearing or a total of eight, as mentioned earlier under Test Procedure. Using the four jets on each bearing, the outer race stabilization temperature for the test bearings, at Test Condition 3, was reduced to a maximum of 315°F, with some of the bearings stabilizing as low as 300°F.

This letter represents the report required by Contract DLA900-79-C-1266, Modification P00019, and completes the requirements of the contract.

If you have any questions relative to the bearing endurance tests performed, please feel free to contact the undersigned.

Respectfully submitted,

B. B. Baber
Assistant Director
Department of Fuels &
Lubrication Technology

BBB/gt

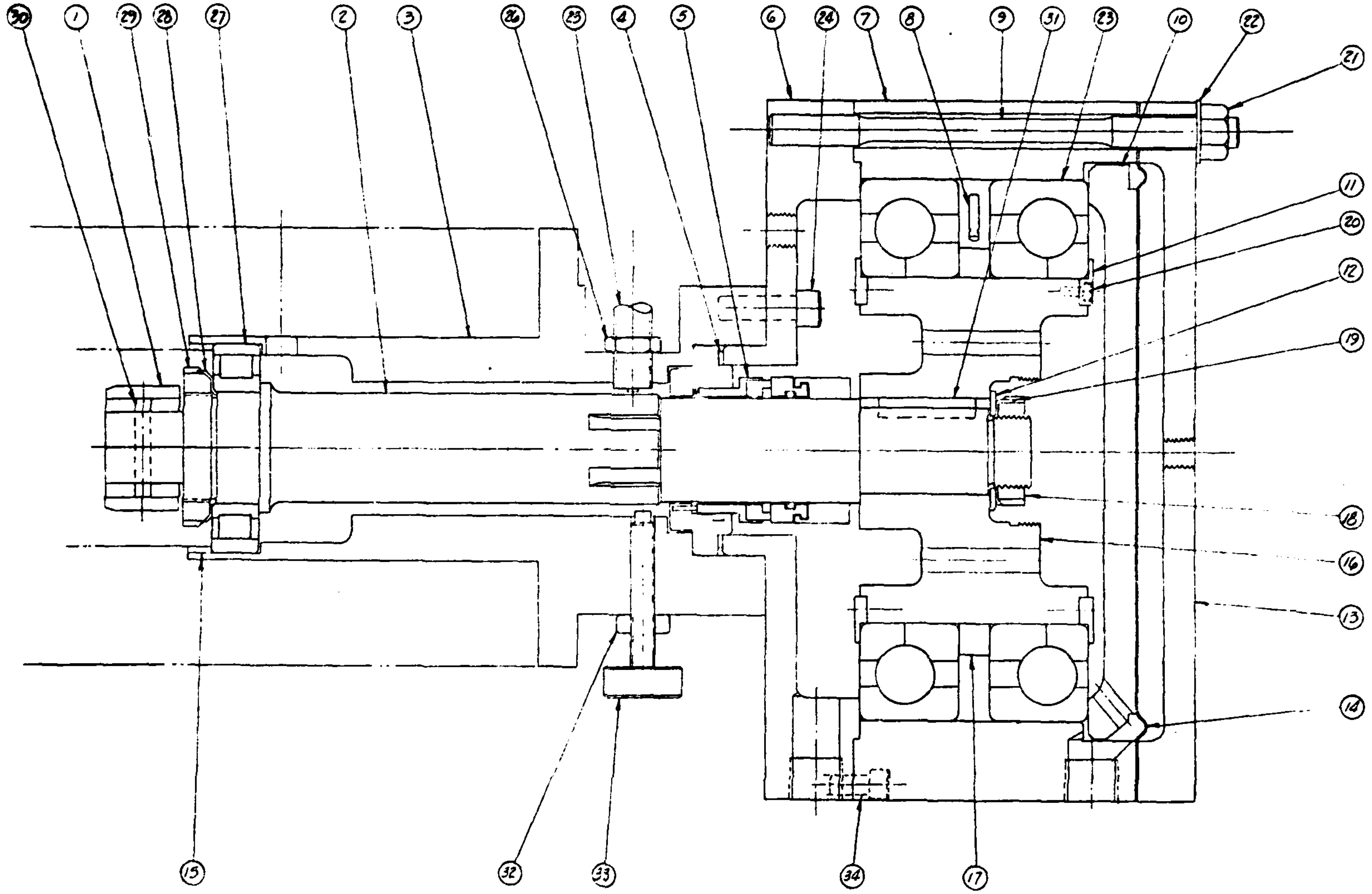
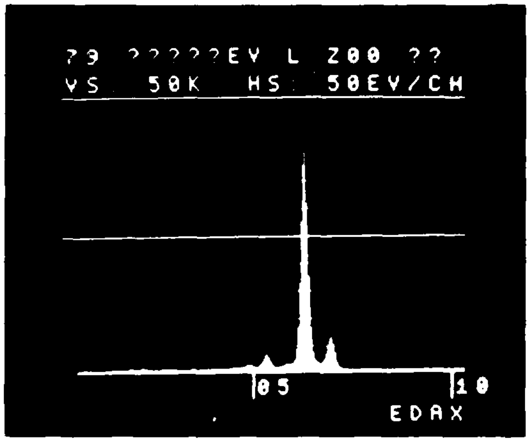
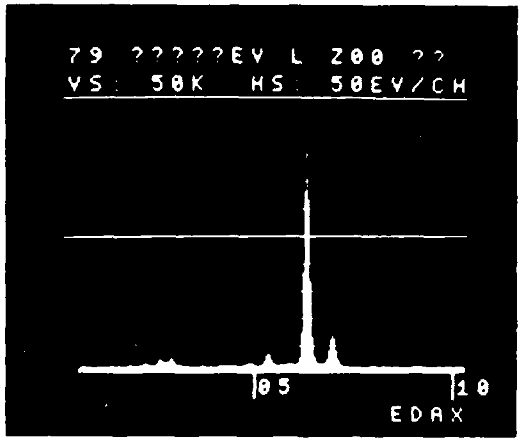


FIGURE 1. THRUST BEARING MACHINE

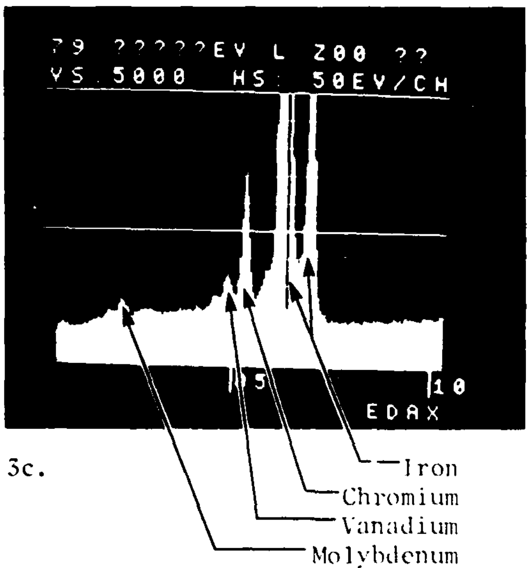
FIGURE 2. TYPICAL SILVER SPOT ON BALL
FROM BEARING NO. 85



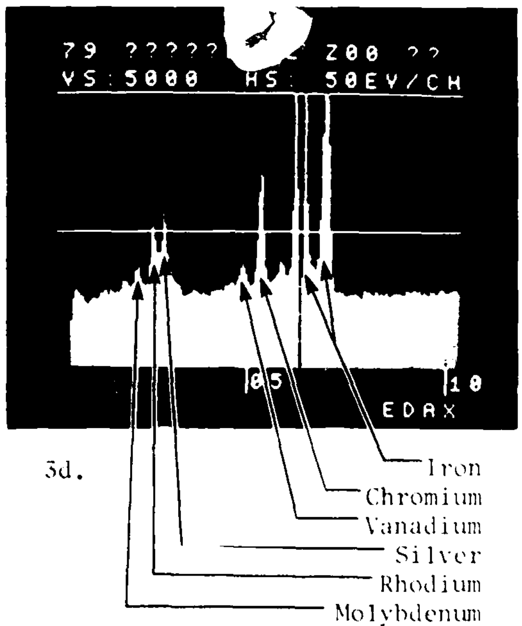
3a. Surface Area Outside Bright Spot



3b. Surface [illegible]ea Inside Bright [illegible]



3c.



3d.

FIGURE 3. EDAX CHARTS OF SELECTED BALL AREAS

FIGURE 4. SPALL ON INNER RACE OF BEARING NO. 85 IN THE AREA OF A SILVER SPOT

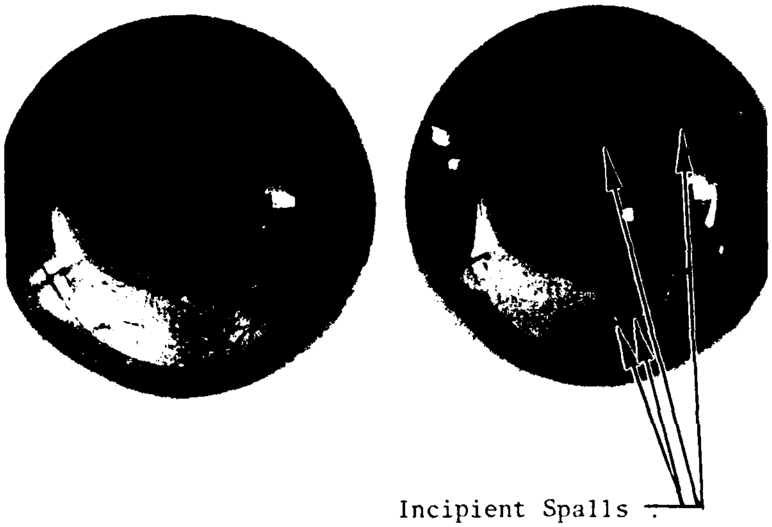


FIGURE 5. SPALLS ON BALLS FROM BEARING NO. 810 IN THE AREAS OF SILVER SPOTS

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